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(54) Smart antenna receiver and signal receiving method

(57) A smart antenna receiver in a CDMA communication system and a signal receiving method therefor. Radio signals received respectively through a plurality of antennas (X1) are multiplied (210) by adaptive weights (W1) and the multiplied signals are summed up (220), thus to generate an array output signal (y). The array output signal is multiplied (240) by a pseudo noise code (260) detected from the pilot signal to generate a despread signal, and the despread signal is filtered (250). The amplitude of the filtered signal is adjusted (270) and then multiplied (280) by the pseudo noise code (260) to generate a reference signal (Y_d). The difference between the reference signal and the array output signal is calculated (290) to generate an error signal (ε). Thefore, an optimal adaptive weight is generated (230) by the error signal and the radio signals.

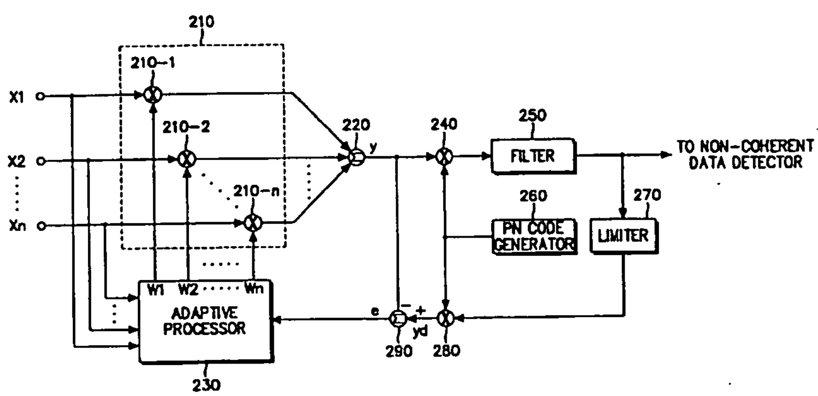

FIG. 2

EP 0 899 894 A2

Description

[0001] The invention relates to a mobile communication system, and more particularly, to a smart antenna receiver in a CDMA (Code Division Multiple Access) communication system and to a signal receiving method therefor.

[0002] A smart antenna receiver using an adaptive antenna array technology automatically adjusts an antenna to the optimal direction according to information obtained by receiving an input signal by respective elements.

[0003] As indicated in FIG. 1, a conventional smart antenna receiver is comprised of a multiplier circuit 110 including a plurality of multipliers 110-1,...,110-n formed correspondingly to an adaptive antenna array, a summer 120, and an adaptive processor 130 for adjusting adaptive weights.

[0004] In operation, array input vector signals X1,...Xn received from a plurality of antennas of an adaptive array are respectively applied to the multipliers 110-1,...,110-n where they are multiplied by weights W1,...,Wn of complex numbers adjusted adaptively by the adaptive processor 130. The output signals generated from the multipliers 110-1,...,110-n are supplied to the summer 120 where they are summed up to generate an array output y. Thus, in a receiving beam pattern, the gain is increased in the direction of a received signal which includes the desired information whereas a null is formed in the direction of a received interference signal, so that a signal can be spatially selectively received. For that reason, the circuit shown in FIG. 1 is called a spatial filter. The spatial filter increases the capacity of a system by reducing the interference between the same channels in a CDMA mobile communication system.

[0005] The adaptive processor 130 of the conventional antenna receiver adjusts the adaptive weights W1,...,Wn only using the array input vector signals X1,...,Xn and the array output y. The adaptive processor 130 carries out complicated calculation processes of searching for the direction of a signal source by calculating an optimal weight, for including those for obtaining an autocorrelation matrix of a received vector signal, and for obtaining an inverse matrix and a unique vector of the autocorrelation matrix.

[0006] Therefore, it takes much time for the adaptive processor to process the calculations, and the circuit of the adaptive processor is complicated. Consequently, it is difficult to apply the conventional smart antenna system to the CDMA mobile communication system.

[0007] It is therefore the object of the invention to provide a smart antenna receiver and a signal receiving method in a CDMA mobile communication system allowing for simplified calculation processes carried out by the adaptive processor.

[0008] This object is solved by the subject matters of independent claims 1 and 10.

[0009] The invention is advantageous in making use of the information about the differences between the desired signal and the interference signal in a more effective way than conventional receivers and methods do.
Moreover, it is advantageous to use the pilot signal in the receiver and the method according to the invention, since the pilot signal is also used to coherently detect data in a reverse link of the CDMA system

[0010] Preferred embodiments are defined by the dependent claim.

[0011] The invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a circuit diagram of a conventional spatial filter; and
FIG. 2 is a circuit diagram of a spatial filter according to a preferred embodiment of the present invention.

[0012] In general, if data is coherently detected by using a pilot signal in a reverse link of a CDMA system, a pilot PN (Pseudo-Noise) code of a desired user can be extracted without particular processing. Since the pilot signal has great correlation with the desired signal and no correlation with any interference signal, the pilot signal in the reverse link can be used in an adaptive processor of a smart antenna receiver.

[0013] As illustrated in FIG. 2, a smart antenna receiver according to a preferred embodiment of the invention includes a multiplier circuit 210, a summer 220, an adaptive processor 230, multipliers 240 and 280, a data bandwidth filter 250, a PN code generator 260, a limiter 270, and a subtracter 290.

[0014] A plurality of linearly or circularly arranged antennas receive radio signals X1,...,Xn. The multiplier circuit 210 includes a plurality of multipliers 210-1,...,210-n connected respectively to the antennas and multiplies the radio signals X1,...,Xn by adaptive weights W1,...,Wn. The summer 220 sums the outputs of the multipliers 210-1,...,210-n to generate an array output signal y. The adaptive processor 230 adjusts the adaptive weights W1,...,Wn by performing an adaptive algorithm using an error signal ε generated from the subtracter 290 and using the radio signals X1,...,Xn. The PN code generator 260 generates a pilot PN code from a received pilot signal in the reverse link. The multiplier 240 multiplies the pilot PN code by the array output signal y generated from the summer 220. A reference signal generating loop including the filter 250, the limiter 270 and the multiplier 280 generates a reference signal y_d used for the adaptive algorithm of the adaptive processor 230. The subtracter 290 generates the error signal ε corresponding to the in phase or time aligned difference between the reference signal y_d and the array output signal y.

[0015] If the desired signal and the interference signal are received by the antennas from different directions,

an adaptive weight W is adjusted such that a main robe of a receiving beam pattern is toward the desired signal and a null of the receiving beam pattern is toward the interference signal. In order to adjust the adaptive weight W, the array output signal y, that is, a linear coupling of data vector (x) components of the radio signal X1,...,Xn should approximate to the desired signal y_d. In this case, $y = W \cdot x^T$.

[0016] In a least mean square (LMS) algorithm given by the following equation, the adaptive weight comes to converge upon an optimal adaptive weight for minimizing a mean square error (MSE) through repeated weight updating. The operation implemented by the adaptive processor 230 for obtaining the optimal adaptive weight can be represented by:

$$W(k+1) = W(k) + 2\mu\varepsilon^{*}(k) \cdot x(k) \qquad (1)$$

where k is a variable for counting time in units of a discrete time such as an adaptive period, μ a scalar constant for adjusting an adaptive rate and stability, ε an error signal (y_d-y), and * indicates complex conjugation.

[0017] To obtain the array output signal y used to calculate the error signal ε, the radio signals X1,...,Xn received at the respective antennas are supplied to the multipliers 210-1,...,210-n where they are multiplied by the adaptive weights W1,...,Wn provided from the adaptive processor 230. The signals produced from the multiplies 210-1,...,210-n are then applied to the summer 220 to generate the array output signal y.

[0018] To obtain the reference signal y_d needed to calculate the error signal ε, the array output signal y is applied to the subtracter 290 and the multiplier 240. The array output signal y applied to the multiplier 240 is multiplied by the pilot PN code generated from the PN code generator 260. The pilot PN code is the same as the PN code which has been multiplied by the signal of the desired user. Then the desired signal is despread by the multiplier 240 and its bandwidth is reduced to a data bandwidth. An interference component remains in a spread bandwidth. While the output of the multiplier 240 passes through the data bandwidth filter 250, the desired signal remains and the interference component except an intermediate bandwidth is eliminated. The output of the filter 250 is applied to limiter 270 for adjusting the amplitude of the reference signal y_d. The output of the limiter 270 is applied to the multiplier 280 where it is multiplied by the pilot PN code and respread. Thus the reference signal y_d is generated.

[0019] The array output signal y and the reference signal y_d generated respectively from the summer 220 and the multiplier 280 are then applied to the subtracter 290 where the error signal ε corresponding to the difference therebetween is generated.

[0020] Consequently, while the desired signal passes through a loop consisting of the two multipliers 240 and 280, the filter 250, the limiter 270 and the subtracter 290 without changing, the interference component undergoes a great change in its waveform. Therefore, there is no substantial correlation with the interference between the reference signal yd and the array output signal y.

[0021] The error signal ε is applied to the adaptive processor 230 so as to obtain the adaptive weight W by the above equation (1) together with the data vector x of the radio signals X1,...,Xn. The discrete time k such as an adaptive period and the scalar constant μ needed to obtain the adaptive weight W by the equation (1) are set constant.

[0022] As described above, since the smart antenna receiver uses the reference signal generating loop using the pilot signal and the adaptive processor which applies the LMS algorithm, the amount of calculation can be greatly reduced.

Claims

1. A smart antenna receiver using a pilot signal in a base station of a CDMA mobile communication system, comprising:

   an adaptive processor (230) for generating adaptive weights (W1, W2, Wn) using radio signals (X1, X2, Xn) received respectively at a plurality of antennas;

   a weighting unit (210-1, 210-2, 210-n) for weighting said radio signals using said adaptive weights; and

   an array output signal generator (220) for receiving said weighted signals and for generating an array output signal (y) therefrom;
   characterized in that the receiver further comprises:

   a pseudo noise code generator (260) for generating a pseudo noise code which is detected from said pilot signal and has been used in a transmitter;

   a despread signal generator (240) for generating a despread signal using said array output signal and said pseudo noise code;

   an elimination unit (250) for substantially eliminating interference components of said despread signal;

   a re-spread signal generator (280) for generating a re-spread reference signal (y_d) using the signal output from said elimination unit and said pseudo noise code; and

   an error signal generator (290) for generating an error signal (ε) indicating a difference between said reference signal and said array

output signal, said error signal being input to the adaptive processor, the adaptive processor using said error signal and said radio signals for generating optimal adaptive weights.

2. The receiver according to claim 1 characterized in that the weighting unit includes a plurality of multipliers for multiplying said radio signals by said adaptive weights.

3. The receiver according to claim 1 or 2 characterized in that said array output signal generator includes a summer for summing the weighted signals.

4. The receiver according to one of claims 1 to 3 characterized in that the despread signal generator includes a multiplier for multiplying said array output signal by said pseudo noise code.

5. The receiver according to one of claims 1 to 4 characterized in that said elimination unit includes a data bandwidth filter for filtering said despread signal.

6. The receiver according to one of claims 1 to 5 characterized in that the re-spread signal generator includes a multiplier for multiplying the output of said elimination unit by said pseudo noise code.

7. The receiver according to one of claims 1 to 6 characterized in that the error signal generator includes a subtracter for calculating the difference between said reference signal and said array output signal.

8. The receiver according to one of claims 1 to 7 further characterized by

   a limiter (270) for adjusting the amplitude of the signal output from said elimination unit and for providing the re-spread signal generator with said adjusted amplitude.

9. The receiver according to one of claims 1 to 8 characterized in that said adaptive processor is arranged for generating said optimal adaptive weights W by using the following equation:

$$W(k+1) = W(k) + 2\mu\varepsilon^{*}(k) \cdot x(k)$$

where k is a variable for counting time, μ is a scalar adjusting constant, ε is said error signal, * indicates complex conjugation, and x(k) is a vector component of a radio signal.

10. A signal receiving method using a pilot signal in a CDMA mobile communication system, the method comprising the steps of:

   generating adaptive weights (W1, W2; Wn) using radio signals (X1, X2, Xn) received at a plurality of antennas;

   weighting said radio signals using said adaptive weights; and

   generating an array output signal (y) using said weighted signals;

   characterized in that the method further comprises the steps of:

   generating a despread signal using said array output signal and a pseudo noise code detected from said pilot signal;

   substantially eliminating interference components of said despread signal;

   generating a re-spread reference signal (y_d) using the signal having eliminated interference components and said pseudo noise code; and

   generating an error signal (ε) indicating a difference between said reference signal and said array output signal and using said error signal and said radio signals for generating optimal adaptive weights.

11. The method according to claim 10 characterized in that the step of weighting includes multiplying said radio signals by said adaptive weights.

12. The method according to claim 10 or 11 characterized in that the step of generating an array output signal includes summing the weighted signals.

13. The method according to one of claims 10 to 12 characterized in that the step of generating a despread signal includes multiplying said array output signal by said pseudo noise code.

14. The method according to one of claims 10 to 13 characterized in that the step of eliminating includes filtering said despread signal.

15. The method according to one of claims 10 to 14 characterized in that the step of generating a re-spread reference signal includes multiplying the signal having eliminated interference components by said pseudo noise code.

16. The method according to one of claims 10 to 15 characterized in that the step of generating the error signal includes a subtracting step of calculating the difference between said reference signal and said array output signal.

17. The method according to one of claims 10 to 16 further characterized by the step of adjusting the amplitude of the signal having eliminated interference components and using said adjusted amplitude for generating the re-spread reference signal.

18. The method according to one of claims 10 to 17 characterized in that the step of generating optimal adaptive weights W uses the following equation:

$$W(k+1) = W(k) + 2\mu\varepsilon^{*}(k) \cdot x(k)$$

where k is a variable for counting time, μ is a scalar adjusting constant, ε is said error signal, * indicates complex conjugation, and x(k) is a vector component of a radio signal.

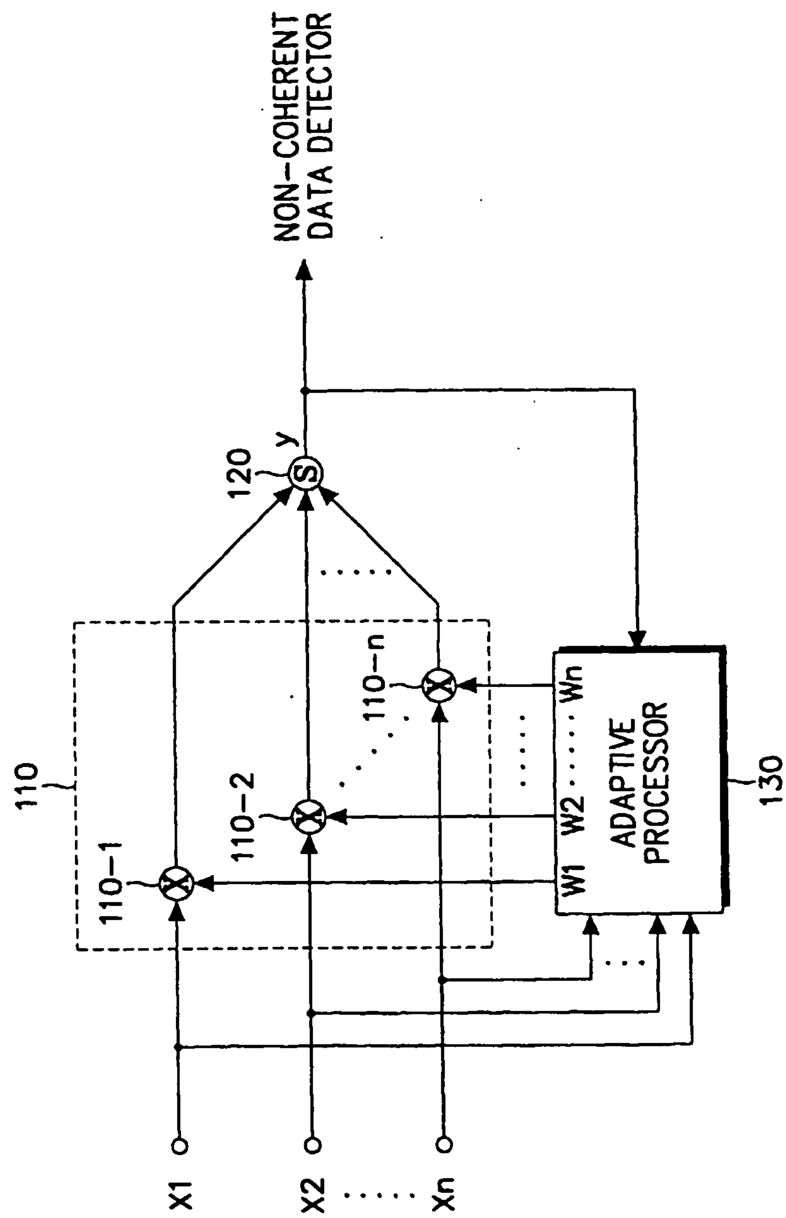
NON-COHERENT
DATA DETECTOR
120
y
S
110
110-1
110-2
110-n
W1
W2
Wn
ADAPTIVE
PROCESSOR
130
X1
X2
Xn

FIG. 1

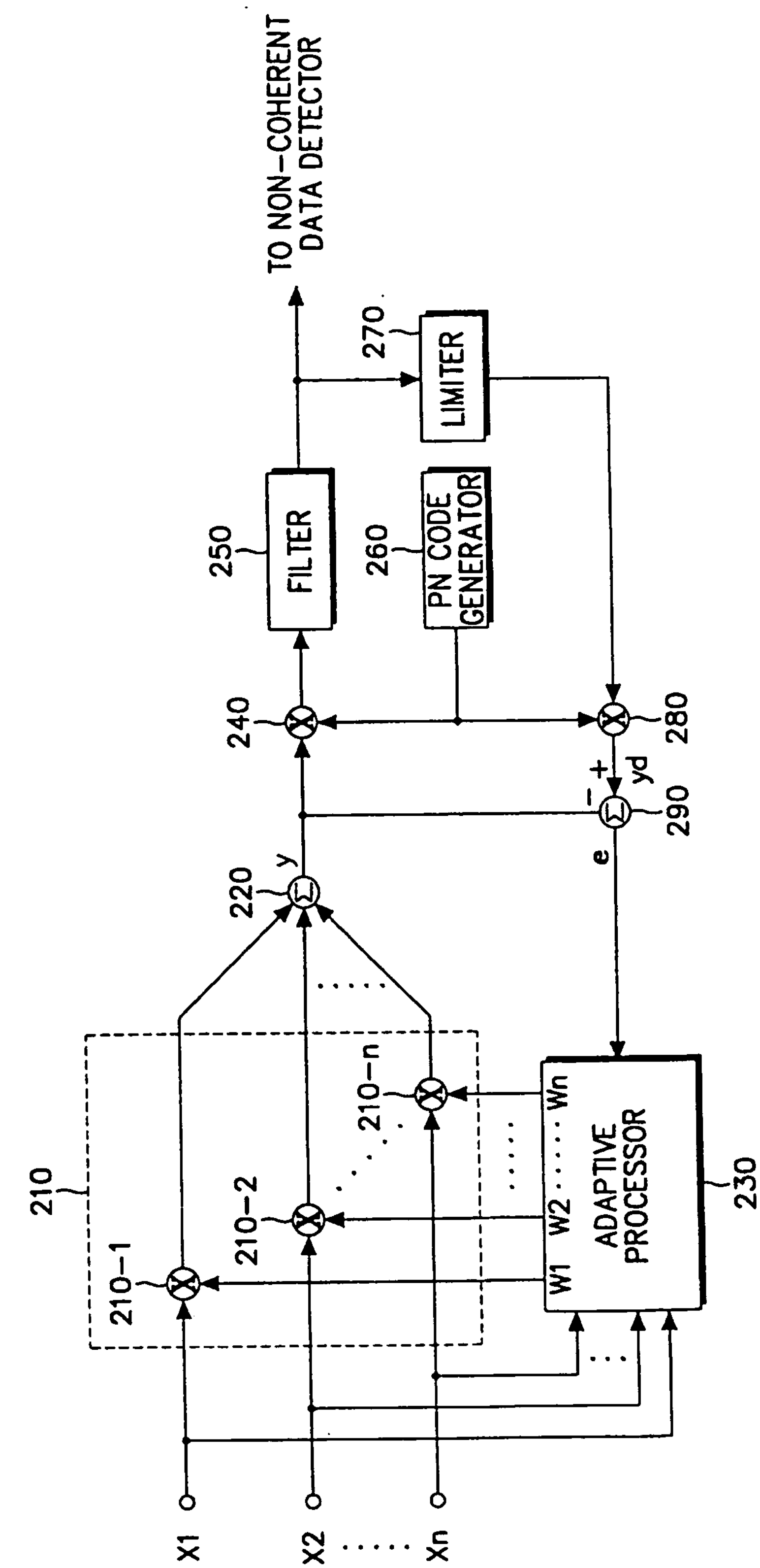
TO NON-COHERENT DATA DETECTOR
270
LIMITER
250
FILTER
260
PN CODE GENERATOR
240
280
+
−
yd
290
e
220
y
210
210−1
210−2
210−n
W1
W2
Wn
ADAPTIVE PROCESSOR
230
X1
X2
Xn

FIG. 2